this crater, which, on plate V, gives the impression of being slightly convex, and has a small crater opening in its center.

The size and shape of this inner crater agrees well in all three cases.

The diameter along the meridian is equal to 3.5 millimetres, or 2.23 kilometres,* or 0.30 geographical miles on the enlargement of 40 diameters, whereas, the diameter of the inner crater-opening is 0.25 kilometres.†

THE CORDOBA DURCHMUSTERUNG.

By R. H. TUCKER, Jr., Astronomer in the LICK Observatory.

The completion of twenty degrees of the *Cordoba Durchmusterung* marks an epoch in that undertaking. The first ten degrees, from -22° Declination, one degree North of the limit of *Schönfeld's Durchmusterung*, to -32°, forms Volume XVI of the *Cordoba Observations*, and has been already distributed to observatories and astronomers, The remaining ten degrees, to -42° Declination, are in the hands of the printer, and will be included in another volume. The maps to accompany the volumes, giving all the stars of the catalogue, are, some of them, now being lithographed.

The two volumes give the places and magnitudes of more than 340,000 stars down to the tenth magnitude. As the region covered by this section of the *Durchmusterung* is three-tenths of the Southern sky, and but thirty three-hundredths remain to the pole, about half the surface included in the original scheme has been completed.

The observation of the twenty degrees has required five years of effective work for the two observers engaged upon it. During this period more than 1600 individual zones were taken, one hour long at the maximum, and one degree of Declination in width, except in portions of the Milky Way, where but 40′ wide was possible. This covers the lap necessary between succeeding zones in Declination ; the zones broken by clouds, or repeated from suspicion that the sky may not have been per-

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* 1 $\frac{1}{10}$ English miles.

† $\frac{1}{100}$ English miles.

fectly clear; the narrow ones of the Milky Way; those lost by failure of the chronograph to record; and short zones to fill in the gaps caused by the various sources of interruption. Some portion of the region South of 42° has also been observed.

Since the Moon deprived us of one-third the nights, and shortened the working hours of one-half the remainder each month, but one-third of the whole month could be counted upon for entirely dark nights. One-half the nights have been cloudy on the average, so that during the period over which the work extends, including the Revision, there has been an average of less than ten nights per month upon which satisfactory *Durchmusterung* observations could be made.

The maximum is reached in the month of August, the end of winter and the last of the dry season, when the average for the month was 12.8 nights. October, in the beginning of the rains, has the smallest average, 7.3; while, in the height of summer, January reaches 11.7 nights.

The periods of six months, corresponding to dry and wet seasons, give almost identically the same amount of observing weather. In the commencement four zones were taken each night, later increased to six, for some months; but, as recorders were not available for these longer nights, five zones have usually constituted a full night's observing. The greatest number in any one month was that of August, 1886, when sixty-seven zones were observed on eighteen nights.

The observer retained his position uninterruptedly during each zone, without removing his eye from the telescope. The number of stars in individual zones ranges from 300 to 1400, and 4500 have been observed in one night. Notwithstanding the large number of stars to be taken as they cross the scale in the center of the field, the collection and comparison of various zones covering the same region, shows that but few are omitted that have been estimated at any time as brighter than tenth magnitude. These have been looked up on Revision, and the great majority of those observed once only in the original zones as 9¾, have been found to be as faint as tenth magnitude, very often below that type.

The tenth magnitude as observed was an elastic type, and intended to include stars slightly in doubt as to falling within the limit; and when there might be a suspicion that the sky was not of the usual transparency, faint stars were purposely included.

Accordingly, those having but one observation as ten, have generally not been again looked up, and do not enter the catalogue.

The estimates of individual magnitudes have often, necessarily, been very hurried, especially since in the densest regions the stars do not lie uniformly distributed, but appear in irregular masses. In general, however, the estimates will not suffer from the need of quick judgment. Long-continued practice in just this class of work has given a facility and a steadiness to the observers that could be gained in no other way. The faculties are trained to alertness; there is usually no time for a second or revised estimate without risk of neglecting other stars hurrying on, and one's observing habit becomes molded to the needs of the service.

The observing was done in a perfectly darkened room, the scale for the determination of positions being visible against the starlit sky. None was carried on when there was a sensible amount of moonlight, nor when there was cloudy sky in the region at which the telescope was pointed.

The continuity of the work, its extensiveness, and the uniformity of the conditions under which it was performed, should render the magnitudes reliable. This is of primary importance, for, next to the completeness of the catalogue, its usefulness to the working astronomer will depend upon this feature.

The *Durchmusterung*, including the Northern one of ARGELANDER and that of SCHÖNFELD, serves as the basis of series of zones of accurate places of stars down to a limiting magnitude, brighter than the limit of the *Durchmusterung* itself. Such a series has been carried to completion in the Northern sky, under the auspices of the *Astronomische Gesellschaft;* the Albany and Cambridge Observatories having borne a part. The list of stars to be observed is taken directly from the corresponding *Durchmusterung*. The scale of the succeeding zone will be, perhaps insensibly, somewhat adapted to that of the working list. Uniformity is then essential throughout, and the type which limits the plan of the zone should be as nearly as possible the true one.

In current observing the astronomer has continually to refer to his *Durchmusterung*, to obtain the configuration of stars near some object whose place is to be determined, probably by differ-

ential measures. In identifying the stars, consistent magnitudes are nearly as useful an aid as the relative positions.

The places are given in the *Durchmusterung* with more than sufficient exactness to serve both purposes: to form a working list for observations of high precision, and for the identification of any star by its relative position to others. The maps will be less consulted, except for the brighter grades of stars, for this last purpose, than the catalogue itself. The formation of the catalogue lends itself to these uses with great facility.

The magnitudes were estimated to the nearest quarter, and since there are always two or more observations of each star, the mean gives the adopted magnitude to tenths. Comparing, during the progress of the current reduction, many regions covered by the same observer, and identical in two zones, so that all stars of one are included in the other, more than one-half the estimates agree in giving the same quarter, and the average difference of estimate is less than one-eighth of a magnitude.

The greatest differences are in estimates of the brighter stars, but these have been in large part estimated again during the Revision.

A useful check during the progress of the work was the count of magnitudes as observed, by grades, to test personal bias towards certain quarters. While the object of this was not to avoid any particular quarter in succeeding work, it served to attract the observer's attention strongly towards the need of exercising an even and wakeful judgment.

The accompanying percentage is the result of a large number of counts for the same observer, for the scale from nine to ten: the even ninth magnitude is in excess, while the large percentage of tenth shows the tendency to include fainter stars. Some of these last will fall into brighter grades in the catalogue, while many will be dropped, from having but one observation:

ESTIMATES OF MAGNITUDES BY QUARTERS.

Brighter than	9	mag.	Percentage, .099
	9	"	" .068
	9¼	"	" .043
	9½	"	" .096
	9¾	"	" .146
	10	"	" .548

Tests, by counts from the catalogue, of each tenth of a magnitude, show that the accumulation of observations has resulted in the whole scale being pretty fairly represented, with tendency to grouping at the even and half magnitudes. The table gives the percentage, as results of counts extending over the first ten degrees, for the first six hours, 29,000 stars having been counted.

The proportion of tenth magnitude stars indicates that this type undoubtedly includes those one-tenth of a magnitude fainter of the same scale, and probably somewhat more.

COUNT OF STARS OF THE CATALOGUE.

0^h to VI^h $-22°$ to $-31°$

Brighter than	7	mag. Percentage	.007
	7.0	" "	.002
	7.1	" "	.001
	7.2	" "	.002
	7.3	" "	.002
	7.4	" "	.001
	7.5	" "	.003
	7.6	" "	.001
	7.7	" "	.003
	7.8	" "	.003
	7.9	" "	.002
	8.0	" "	.006
	8.1	" "	.004
	8.2	" "	.005
	8.3	" "	.006
	8.4	" "	.005
	8.5	" "	.012
	8.6	" "	.009
	8.7	" "	.013
	8.8	" "	.011
	8.9	" "	.103
	9.0	" "	.025
	9.1	" "	.025
	9.2	" "	.026
	9.3	" "	.032
	9.4	" "	.034
	9.5	" "	.055
	9.6	" "	.066
	9.7	" "	.090
	9.8	" "	.092
	9.9	" "	.090
	10	" "	.354

The magnitudes observed were often tested during reduction of the observations, by comparison with the stars of the Cordoba Zone Catalogue, used to obtain the constants of reduction for the places of the *Durchmusterung*. These tests agree, over a long period, in giving a pretty consistent difference for the same observer of 0.17 mag. throughout the range from 7 to 9; the Zone Catalogue estimates being fainter. For stars fainter than 9 in the Zone Catalogue, the difference in the magnitudes at once increases, and it seems probable that the fainter estimates of that catalogue, especially ten, of which but few were made, were obtained under observing conditions less favorable than usual.

The proportion of D. M. stars, observed in the Zone Catalogue, was found to be 0.100; from the number used in the reduction of a large part of the work. But this is not a complete count.

The number of stars contained in the Zone Catalogue would give 33,000 as the proportional number from $-23°$ to $-42°$. Though not intended in any measure to be complete beyond the eighth magnitude, it could be considered as extending to an equivalent limit slightly fainter than 8.8 of the D. M. scale, the stars observed fainter than that limit balancing in number, approximately, those omitted between 8 and 8.8.

The percentages of stars of each magnitude, in the first six hours of the Northern ten degrees of the *Durchmusterung*, afford a test of the magnitudes themselves, on the basis of the distribution of the stars at distances corresponding to their brightness. The inference would be that tenth magnitude stars would be represented by 9.9 of the D. M. scale, and that the 10 of that scale would be mainly 10.1 and 10.2.

This is additional assurance that the catalogue is complete to the tenth magnitude, while any type of magnitude brighter is not likely to be more than one-tenth of a unit in error.

The probable error of a single observation of position, from a large number of determinations made during reduction, by comparing pairs of observations by the same observer, was $\pm 0.7^s$ in Right Ascension, and $\pm 0'.33$ in Declination. While in Right Ascension the probable error is less than half that of Declination in arc, it may seem large for transits; but in observing the brighter stars there is an uncertainty in estimating the instant of disappearance behind the scale, hardly to be compared with that of the bisection of a star by transit threads.

The probable error of the final place of the star is not much

affected by the error of reduction, it is mainly due to observation. But in Declination there is always a factor, due to the estimation of the divided scale to a certain fractional part—tenths of a division in this case corresponding to whole minutes of arc.

A test of personal bias in observing the declinations was made at various times during the reduction, by counting the units of the scale. This being reckoned from 20 to 80, the number 0 would naturally be in excess of the others; and as both 19 and 81 were often included, the units 1 and 9 show the effect. The table of percentages, which gives the result of a large number of counts at different epochs, for the same observer, shows also a tendency to avoid the unit 5.

COUNT OF UNITS OF DECLINATION SCALE.

Scale	0	Percentage	.145
"	1	"	.118
"	2	"	.095
"	3	"	.095
"	4	"	.085
"	5	"	.073
"	6	"	.087
"	7	"	.109
"	8	"	.083
"	9	"	.110
"	0	"	.145

Following the original zones of the *Durchmusterung*, the Revision was devoted to clearing up all cases of doubtful identity, of magnitude, and of place, that were found in collecting and combining the various observations of the same region. This covered twenty months of effective observing, and was finished in the month of March of this year.

The reduction of this great mass of observations has required the nearly undivided labors of three men for the period which the observing has occupied. This carries it through publication, but the map-drawing is not included.

The current observing was usually brought up and reduced month by month; the combination followed when a sufficient amount had accumulated, and the collected results were given a thorough scrutiny preparatory to the Revision.

The prompt publication of the results of the *Durchmusterung*, following upon its vigorous prosecution, has been quite in the spirit which has governed the previous undertakings of the Cordoba Observatory.